Price Transmission in the Swedish Pork Chain: Asymmetric non linear ARDL

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1. Introduction

The volatility of food prices, both horizontally and vertically, have been of great concern to economists, policy makers, and stakeholders in the agri-food industry. Horizontally the issue is usually referred to as the law of one price (LOP) and concerns the price differentials of the same products between different regions. The vertical price level and variability, refers to two aspects: First, the size and volatility of marketing margins, i.e. the spread between producer and consumer prices. A second, and related, issue is the transmission of prices between the various stages in the food chain. It is important here to distinguish between analyses of evolution of margins over time and price transmission as these topics are closely related but are not identical. Conclusions about price transmission that are drawn from the evolution of marketing margins over time, but do not incorporate other information such as the changes in the costs of other inputs, may well be misleading. In particular of great interest is whether the transmission of prices is symmetric in terms of price increases and decreases. Furthermore, the subject of price transmission has been increasingly linked to the discussion about benefits from agricultural reform (Vavra and Goodwin, 2005). A common concern of policy makers relates to the assertion that, due to imperfect price transmission a price reduction at the farm level is only slowly and incompletely transmitted through the supply chain. In contrast, price increases at the farm level are thought to be passed more quickly on to the final consumer.

In this paper we focus on the analysis of vertical price transmission in pork prices between producers, wholesalers and consumers in Sweden in the long and in the short run.

2. Asymmetric Price Transmission

In his survey on marketing margins in the agri-food industry, Wohlgenant (2001), identifies some of the key questions related to this issue: Are marketing margins too large? Why are margins different among products? How have margins changed over time? What is the incidence of marketing costs on retail prices and farm prices? How quickly are farm prices transmitted to the retail level and vice versa? What is the relationship between concentration and market power? Is increased concentration detrimental or beneficial to producers? (see also Vavra and Goodwin, 2005). These questions have attracted increased attention among researchers and policy circles. For example, in a recent study by the European Commission (EU-COM 2009) it was found that price formation along the food supply chain depends on several factors, such as the intrinsic specificities of the product (storability, seasonality), the market structure and organization (the degree of competition at the different stages, number of intermediate stages) along the supply chain as well as public policy schemes and legislation. These pretty much reflect most findings in this very extensive literature (for a recent survey see Meyer and von Cramon-Taubadel, 2004).

Market power is often suggested as an explanation for asymmetric price transmission, where agents in the intermediates stages in the food supply chain exercise market power and influence the price adjustment process to their advantage both upstream towards the farmers and downstream towards the final consumers, (i.e. positive asymmetric price transmission). This could be through a oligopoly and/or oligopsony market situation, which causes price distortions and lags in the price adjustment process. Many studies argue that market power leads to positive asymmetric price transmission, which also seems logical in a pure monopoly context (Meyer et al 2004). A kinked demand curve is also proposed as the usual suspect (Scherer, 1996; Beily and Brorsen, 1989) for asymmetric price transmissions. If a firm believes that no competitor will match a price increase but all will match a price cut, a negative asymmetry will result. Otherwise if the firm conjectures that all firms will match an increase but none will match a price cut, positive asymmetry will result.

However, the evidence concerning the effect of market power on price transmission asymmetry is unclear on both theoretical and empirical grounds. Peltzman (2000, p. 493), ascertains that price asymmetry is as characteristic of "competitive" as "oligopoly" market structures. In an empirical study on a broad såectrum of prices, Peltzman (2000) uses two proxies for market power, number of firms and HH index and finds conflicting results: While a small number of firms increases the magnitude of price transmission asymmetry, the degree of concentration measured by the HH has opposite effects. Weldegebriel (2004) argued that oligopoly or oligopsony power per se does not necessarily mean imperfect price transmission; showing that the functional forms of retail demand and farm input supply are key factors in determining the level of price transmission. Azzam (1999), has shown that asymmetry can occur even in a competitive environment due to intertemporal optimizing behavior.

Furthermore, public policy schemes can affect the asymmetric price transmission. For example, Kinnucan & Forker (1987) argue that floor prices can lead to asymmetric price transmission if they lead wholesalers or retailers to believe that a reduction in farm prices will only be temporary because they will trigger government intervention, while an increase in farm prices is more likely to be permanent.

Although the list of possible causes of asymmetric price transmission is not exhaustive, we conclude this list by one frequently sitedcited parameter, namely asymmetric information costs between producers, and especially wholesalers and retailers (Bailey & Brorsen, 1989). The effect of cost structure on asymmetric transmission is discussed below.

3. Long-run and Short-run Price Transmission Asymmetries: The effects of costs

Price transmission asymmetries may vary with the length of run. One possible explanation is returns to scale which may vary between the short and the long run. Another reason might be adjustment costs that may also be very high in the short run and may delay price adjustments.

A number of studies consider the structure of costs and their interaction with market power as causes of price transmission asymmetries. Bettendorf and Verboven (2000) showed that the weak transmission of coffee bean prices to consumer prices in the Netherlands was due to a relatively large share of costs other than the costs of beans while the market was relatively competitive. McCorriston, et. al. (2001) using a theoretical model and numerical simulations show that the interaction of economies or diseconomies of scale with market power can cause price transmission asymmetries, while market power alone can be irrelevant. The authors derive the price transmission elasticity and they show that it depends on the interaction between market power and scale economies. If the cost function is characterised by increasing returns to scale, the influence of market power might be offset by the costs effects of scale enlargement and the level of price transmission elasticity may increase relative to the competitive case. McCorriston, et. al. (2001) also find that price transmission depends much on the functional form of the demand.

Capital and technology adjustments in the long run may exhibit increasing returns to scale, causing differential impacts of price transmission in the long and short run. Although increasing returns should not be overruled in the short run (McCorriston, et. al., 2001) it is reasonable to expect differences in scale economies.

Adjustment costs (often referred to as menu costs) in especially the retailing sector could cause some degree of price rigidity, because it is costly to change prices. Levy et al. (1997) and Dutta et al. (1999) provide evidence of menu costs at the retail level, while Beily and Brorsen (1989) consider costs of adjustment of beef packers vis-à-vis those of feedlots. Inventory management can also affect the price transmission, by creating lags in adjusting prices (Balke et al., 1998; Blinder, 1982).

4. The nature of asymmetric price transmission

Asymmetric price transmission can take various forms depending on four elements (Vavra and Goodwin, 2005):

I. **Magnitude**. How big is the response at each level due to a shock of a given size at another level?
II. **Speed**. How fast is the adjustment process?
III. **Nature**. Are positive and negative shocks at a certain marketing level exhibit asymmetry?
IV. **Direction**. Is the shock transmitted upwards or downwards the supply chain?

In the Figure 1 we illustrate a positive and a negative asymmetry.

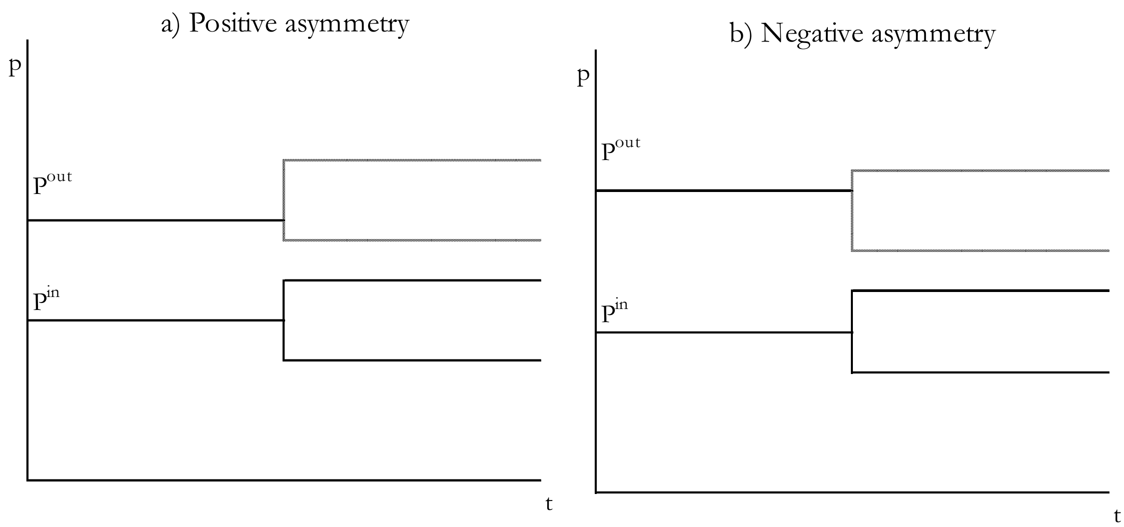

Figure 1. Types and size of Asymmetric Price Transmission

5. Methodology

There exist a large number of studies examining price transmission in agricultural commodity markets. The choice among various possible techniques applied in each of these studies depended on the questions asked, the data used and the assumptions made (Vavra and Goodwin, 2005). A review of the empirical issues underlying this literature can be found in Wohlgenant (2001), Meyer and von Cramon-Taubadel (2004), and Frey & Manera (2007). A comprehensive review of estimating and testing for asymmetric price transmission is provided in Meyer and von Cramon-Taubadel (2004) who provide a categorization into pre- and post-cointegration techniques. A typical pre-cointegration study involves a regression of price differences on lagged price differences, where the lagged differences are segregated according to sign, so that positive changes are allowed to have a different effect than negative changes. These types of studies can be traced back to Tweeten and Quance (1969), who use a dummy variable technique to estimate irreversible supply functions. Based on Tweeten and Quance, Wolffram (1971) employ a variable-splitting technique that explicitly includes first differences of prices in the equation to be estimated. A turning point in these type o studies is Houck (1979), and later Ward (1982). Houck (1982) modified the variable splitting technique further to exclude the initial observations. Ward (1982) extends Houck’s approach by including lags of the exogenous variables such that the delay in effects and the length of lags can differ depending on whether the causal price is increasing or decreasing. Boyd and Brorsen (1988) were the first to use lags to differentiate between the magnitude and the speed of transmission.

Although these techniques were used extensively they were not without faults. Von Cramon-Taubadel and Fahlbusch (1994) pointed out the potential for spurious regression in the case of asymmetry tests if these are estimated without regard to the possible non-stationarity of price series. They suggested that in the case of cointegration between non-stationary series, an error correction model provides a more appropriate specification for testing asymmetric price transmission. Tests that do not consider cointegration risk bring biases because if there is no cointegration there is no price transmission which means there cannot be any asymmetric price transmission either, and the results will have no economic meaning since the two prices have no relationship (von Cramon-Taubadel & Loy, 1996).

The majority of studies related to asymmetric price transmission rely on the Johansen method or the Engle-Granger two-step technique for cointegration. These methods, in turn, imply a linear long-run relationship. The imposition of linear long-run relationship might lead to misleading and spurious results, when the cointegration relationship, in fact, is nonlinear. In this paper we deal with this problem in a systematic way.

6. Model Structure of the Asymmetric ARDL Model

If cointegration really exists it is possible to further analyze in what way price changes will be transmitted, i.e. if asymmetric price transmission is present, this is preferably done with an asymmetric error correction model. One aspect regarding this method should be highlighted. Since cointegration is based on the idea of a long run equilibrium relationship between two series, it will prevent the input and output prices from drifting apart. Because of this it is only possible to analyze asymmetry in the short run with respect to the speed of adjustment. Analysis of the magnitude of the asymmetry is not possible. This is because asymmetry with respect to magnitude means that there is a permanent divergence between positive and negative price changes which in the long-run means that the series, cannot be cointegrated. Another disadvantage is that if there is asymmetry in the series this might confuse the standard tests such as the Dickey-Fuller unit root test and the Johansen test for cointegration (Vavra & Goodwin 2005).

To be able to handle these problems a few methods have been put forward. One approach is to instead of testing for cointegration to test if asymmetric cointegration is present. Granger & Yoon (2002) and Schorderet (2003) were among the first to bring forward the idea that the cointegration relationship can be defined by the positive and negative components in the underlying variables, an effect that Granger & Yoon (2002) name *hidden cointegration*. To analyze asymmetric price transmission, assuming an asymmetric relationship means a great advantage if the relationship, de facto is asymmetric as this procedure incorporates possible asymmetries in the cointegration test which eliminates the risk of biased results.

In the proposed method by Shin et al. (2009) the cointegration test is made in the regression with the upper and lower bound F-test and W-test proposed by Pesaran et al. (2001). This means that it is possible to avoid the problems with cointegration test using Johansen or Engle & Granger when asymmetries are present. Furthermore the method makes it possible to simultaneously analyze the long run magnitude of the price transmission as well as the short run dynamic adjustment process. This may allow us to disentangle the effects of market power from those of scale and adjustment costs. As we have discussed previously, price transmission can arise because of other reasons than market power such as scale economies and adjustment costs. Price transmission because of scale and adjustment costs will more likely occur in the short run (Meyer & von Cramon-Taubadel, 2004:590) so if one can conclude that the asymmetries also tend to last in the long run there is a greater probability that this asymmetry has arisen because of market power.

6.1 Asymmetric non-linear auto regressive distributed lag model

The linear ARDL approach is an efficient technique for determining cointegrating relationships in small samples and also has the additional advantage that it can be applied irrespective of the regressors' order of integration (Pesaran and Shin, 1998); that is, it can be applied regardless of the stationary properties of the variables in the sample, thus allowing for statistical inferences on long-run estimates which are not possible under alternative cointegration techniques. Hence, we are not concerned whether the applied series are I(0) or I(1).

The asymmetric nonlinear ARDL model (NARDL) applied in this paper is a relatively new technique for detecting both long- and short-run asymmetries between economic variables. The model was advanced by Shin, Yu and Greenwood-Nimmo (2009) and is an asymmetric expansion of the above mentioned linear ARDL model. Following Pesaran and Shin (1998), Pesaran, Shin and Smith (2001), Schorderet (2004) and Shin, Yu and Greenwood-Nimmo (2009), consider the asymmetric cointegrating regression:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t, \tag{1}$$

where β^+ and β^- are the associated long-run parameters while, x_t is a k×1 vector of regressors decomposed as:

$$x_t = x_0 + x_t^+ + x_t^-, \tag{2}$$

x_t^+ and x_t^- are partial sum processes of positive and negative changes in x_t:

$$x_t^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0) \text{ and } x_t^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} \min(\Delta x_i, 0), \quad (3)$$

By associating (3.1) to the ARDL(c, d) case we obtain the following asymmetric error correction model (AECM):

$$\Delta y_t = a y_{t-1} + \theta^+ x_{i-1}^+ + \theta^- x_{i-1}^- + \sum_{i=1}^{c-1} \varphi_j \Delta y_{t-i} + \sum_{i=0}^{d} (\pi_i^+ \Delta x_{t-i}^+ + (\pi_i^- \Delta x_{t-i}^-) + e_t, \quad (4)$$

where $\theta^+ = -a\beta^+$, $\theta^- = -a\beta^-$, $\pi_t^+ = -\beta^+ \varphi_i + \psi_{2i}$, $\pi_t^- = -\beta^+ \varphi_i + \psi_{2i}$ for $i = 1,...,c$.

The Asymmetric ARDL Cointegration approach follows three steps; namely, step one concerns the estimation of the regressors x_t which are decomposed into x_t^+ and x_t^-, and can be estimated simply by standard OLS. Step two is the establishment of the long-run relationship between the levels of the variables y_t, x_t^+ x_t^- (unrestricted error correction mechanism regression), by means of a modified F-test using the bounds-testing procedure advanced by Pesaran, Shin and Smith (2001) and Shin, Yu and Greenwood-Nimmo (2009), which refers to the joint null, $\alpha = \theta^+ = \theta^- = 0$ in (3.4). Step three, refers to the testing by means of the Wald test for: (i) long-run symmetry where $\theta = \theta^+ = \theta^-$, and (ii) short-run symmetry in which $\pi_i^+ = \pi_i^-$ for all $i = 1,...,c$. Finally, the asymmetric ARDL model (3.4) could be used to obtain the asymmetric dynamic multiplier effects of a unit change in x_t^+ and x_t^- on y_t defined by:

$$m_j^+ = \sum_{i=0}^{j} \frac{\partial y_{t+i}}{\partial x_t^+}, \quad m_j^- = \sum_{i=0}^{j} \frac{\partial y_{t+i}}{\partial x_t^-}, \quad j = 0,1,2... \quad (5)$$

Note that as $m \to \infty$, $m_j^+ \to \beta^+$ and $m_j^- \to \beta^-$ where $\beta^+ = {-\theta^+}/{\alpha}$ and $\beta^- = {-\theta^-}/{\alpha}$ are the asymmetric long-run coefficients.

7. Results

Figure 2 shows the pork price evolution for the three levels in the market chain in Sweden. As seen from the figure there has been great variability in all prices. Furthermore, all prices seem to follow a common trend which talks in favor for a cointegration relationship and that some kind of price transmission is present.

Figure 2. Monthly pork price indices of retail, wholesale, and producer in logs

Test for unit root is done using an Augmented Dickey-Fuller and Phillips-Perron test with optimal lag length chosen from Akaike and Schwarz Bayesian information criteria. In Table 1 it is shown that all series are non stationary in levels whilst they are all stationary after differentiation. By that it is possible to say that all pork prices are I(1). With this in mind the analysis goes forward with cointegration test. This is done with Engle-Granger's two step method and Johansen. As seen from Table 1 the results are very ambivalent. A clear result of cointegration is only present in the relationship between producer and wholesale prices. The other two give mixed results. But, as mentioned above, since our data probably is characterized by non-linearity and asymmetric attributes, the results should be construed with caution.

Since the diagram talk in favor for a relationship between the three series this adduces for the ARDL method with asymmetric cointegration. This method is applied to all series and in each direction to control for the causality.

Table 1. Estimation Results

Pork

	R = W		W = P		R = P	
Variable	coefficient	stderror	coefficient	stderror	coefficient	stderror
constant	0.69516***	0.17728	0.52766***	0.14061	0.61026***	0.14306
trend	0.0009601***	0.0003181	–	–	0.0005843**	0.0002529
Ly_{t-1}	-0.15625***	0.039375	-0.11321***	0.0303	-0.13851***	0.031986
Lx^{+}_{t-1}	0.037825*	0.020929	0.058744***	0.02209	0.044488***	0.01511
Lx^{-}_{t-1}	0.12834***	0.040065	0.048162**	0.020188	0.067188***	0.019558
Δy_{t-1}	-0.10431	0.071064	0.015481	0.085757	-0.12099*	0.067084
Δy_{t-2}	–	–	–	–	–	–
Δy_{t-3}	–	–	–	–	–	–
Δx^{+}_{t}	0.37573***	0.077077	0.30291***	0.051671	0.15032***	0.040972
Δx^{+}_{t-1}	–	–	0.18267***	0.065277	0.11536**	0.047307
Δx^{+}_{t-2}	–	–	–	–	–	–
Δx^{+}_{t-3}	–	–	–	–	–	–
Δx^{-}_{t}	–	–	–	–	–	–
Δx^{-}_{t-1}			–	–	-0.080286	0.050853
Δx^{-}_{t-2}	0.20425**	0.092045	0.17893***	0.059572	–	–
Δx^{-}_{t-3}	–	–	0.083581	0.062282	0.034084	0.043176
R^2	0.48071		0.62484		0.46981	
adj, R2	0.43321		0.59052		0.41777	
L^{+}_{y}	0.2145097**		0.518894***		0.4204696***	
L^{-}_{y}	0.8917274***		0.4254262***			
F_{PSS}	–	–	–	–	6.4679**	
W_{PSS}	19.5047**		15.6648**			
W_{LS}	7.5514	[0.006]	13.1255	[0.000]	2.21	[0.137]
W_{KS}	2.0857	[0.149]	4.5097	[0.034]	11.3984	[0.001]

The PSS F-test results in cointegration for all downstream relationships but for none of the upstream. Hence, the results show downstream causality for all stages within the pork sector. Thus, changes in producer prices will affect the wholesale price as well as the retail price, as well as changes in the wholesale price will affect the retail price.

Table 2. Summary Results

	Pork		
Causality	Asymmetry/symmetry Short/long run	Long run parameter (pos/neg)	Pos/neg asymmetry, Short/long run
Producer-->Wholesale	A/A	0.519/0.425	+/+
Producer-->Retail	A/S	0.42	+/S
Wholesale-->Retail	S/A	0.215/0.892	S/-

The wholesale level showed positive asymmetric response to changes in the producer price, both in the short and long run. Where this asymmetry come from is hard to say without any further analysis on the fundamental functioning of this market. The wholesale sector does probably possess some market power against the producers. Since the asymmetry is positive in its nature it is easy at hand to say that is asymmetry is a result of greedy wholesaler who take advantage of price increases on the producer level to quietly raise their prices more than adequate. But, on the other hand, the competition level within this sector is fairly high in Sweden. In the short run the asymmetry can be a result of adjustment costs. Because of biological reasons there is a substantial sluggishness in the adaption to changes in demand within the pork sector. Under these circumstances it is possible that the wholesale sector raises their prices to avoid an empty stock (Baily & Brorsen 1989). In the long run these biological lags and adjustment costs should play a smaller part. Thus can the long run asymmetry, to a greater extend, be addresses to misuse of market power in the wholesale level. Especially since the asymmetry is of positive nature.

The Wald test is unable to reject long-run symmetry between producer and retail price changes. So, in the long run price changes will converge towards a symmetric long run relationship between these two price levels. In the short-run however the negative price changes were insignificant, indicating a short-run asymmetric price transmission. This means that in the short run only price increases are transmitted. Because of the complete lack of price reduction in the short run it is possible to say that the market power might play a significant part in explaining the short run asymmetry here.

The price linkage between retail and wholesale showed a symmetric relationship in the short run but an asymmetric price transmission in the long run. This is a strange result which has not been showed that much in the previous literature. One possible explanation is the biological lags that have been mentioned above. Since the farmer’s supply function is completely inelastic in the short run it will take a few periods before they can adapt to a different demand. If the price change does not have any effect until long run this could explain the results. However the wholesale sector should only be partially effected by this phenomenon and also, the demand factor should not have that big of an impact since it is downstream causality at hand. With this said it can be concluded that more research should probably be pointed towards this phenomenon.

Furthermore, the asymmetry between the retail and wholesale sectors is of negative nature, i.e. the retail level will adjust more extensive and faster on price declines in the wholesale level. The long-run parameters were calculated to 0.215 and

0.892 for positive and negative price changes respectively. So, when the wholesale price increases (decreases) with 10 percent the retail price will increase (decrease) with 2.15 (8.92) percent. An action that is clearly good for the consumers. The Swedish retail sector is characterized by a few dominating firms and high concentration levels (Konkurrensverket 2008). From these facts it is possible to say that the shown asymmetry is a result of oligopoly competition where the retail sector avoids increasing its prices to maintain, or enlarge, their market share (e.g. Ward 1982). However, because of the short run symmetry and the long run asymmetry there might also be something else involved.

8. Concluding remarks

In this study we have investigated the price linkage between different levels within the food market chain in the Swedish pork industry. The combination of asymmetric cointegration and a dynamic ARDL model have made it possible to test for both long-run and short run asymmetries. The establishment of asymmetries in the long run can to large extend can be ascribed to market power.

Although the results are ambiguous showing both symmetric and asymmetric results in some of the price series, they point towards further investigation and analysis.

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